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DYNAMICS OF A LOGGERHEAD SHRIKE POPULATION IN MINNESOTA

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Abstract.—We studied breeding pairs of Loggerhead Shrikes (*Lanius ludovicianus*) in Minnesota from 1986–1988 to identify possible causes of declines in midwestern shrike populations. Data on their reproduction and survival were used to construct a stochastic model of the dynamics of a hypothetical Loggerhead Shrike population based on productivity per pair, annual adult survival rate, and annual juvenile survival rate. The model predicted a 20% mean annual rate of decline for the population, which closely resembles an observed 29% decline in breeding pairs in Minnesota from 1986 to 1987. We conclude that declines in migratory midwestern shrike populations are probably caused by factors outside their breeding range. *Received 27 Feb. 1989, accepted 1 Nov. 1989.*

Loggerhead Shrike (*Lanius ludovicianus*) populations are declining throughout the species' range in midwestern, New England and mid-Atlantic states (e.g., Bystrak and Robbins 1977, Hess 1980, Kridelbaugh 1981, Morrison 1981, Burnside and Shepherd 1985). As a result, the Loggerhead Shrike has been included on the National Audubon Society's "Bluelist," and it currently is considered endangered or threatened by many state natural resource agencies. The Loggerhead Shrike is one of the few species showing significant declines in all continental regions of the Breeding Bird Surveys (Robbins et al. 1986).

Inadequate reproduction has been proposed as responsible for this decline (Gawlik 1988, Kridelbaugh 1983, Luukkonen 1987, Porter et al. 1975, Strong 1972). These studies, however, all concluded that reproductive success was normal, and hence not contributing to population declines. Other studies have focused on the possibility of pesticide poisoning (Anderson and Duzan 1978, Busbee 1977, Morrison 1979). Anderson and Duzan (1978) and Busbee (1977) showed that organochlorines can reduce the thickness of shrike eggshells and retard behavioral development of young. Anderson and Duzan (1978) concluded, however, that a slight 2.57% decrease in the eggshell thickness index from 1895 to 1972 was not hindering reproduction. Furthermore, widescale use of organochlorines was curtailed in the early 1970s, yet Loggerhead Shrike numbers have continued to decline.

Loss of habitat on the breeding range has also been addressed as a possible cause for declines in some local populations (Brooks and Temple

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1990, Gawlik 1988, Luukkonen 1987, Kridelbaugh 1983). However, most studies conclude that availability of breeding habitat is not limiting Loggerhead Shrikes.

In this paper we examine the dynamics of a Loggerhead Shrike population in the upper midwest. We use demographic parameters obtained from our field studies and others in a stochastic simulation model that projects trends in population size. This model allows us to identify the rate of decline of a hypothetical shrike population over a 50-year span of time. We compare the results of our simulations with trends detected by the Breeding Bird Survey and other estimators of population trends, and we discuss some possible causes for the continued decline of midwestern shrike populations.

STUDY AREA AND METHODS

The breeding range of the Loggerhead Shrike in Minnesota is restricted primarily to the southern two-thirds of the state (Brooks and Temple 1986). Our field work took place in 11 counties in southern Minnesota during the nesting seasons of 1986, 1987, and 1988. These counties include Benton, Blue Earth, Clay, Dakota, Fillmore, Goodhue, Lac Qui Parle, Morrison, Redwood, Rice, and Sherburne. The dominant vegetative cover types in these 11 counties are agricultural fields and pastures, with small scattered prairie fragments.

From 27 April through 20 August, 1986, we searched for breeding Loggerhead Shrikes in legal townships (i.e., 36 square mile areas) where they had been reported over the previous 10 years. We also investigated reports of shrikes from cooperating observers who had been solicited through the Minnesota Ornithologists' Union and the Minnesota Dept. of Natural Resources. We searched for birds by driving slowly along county and township roads, stopping to scan areas of particularly good habitat (i.e., Brooks and Temple 1986). From 21 April through 15 June, 1987, and from 14 April through 16 May, 1988, we searched for Loggerhead Shrikes in previously occupied breeding territories and adjacent areas. We found nests by observing the behavior of adults or by thoroughly searching all possible nest trees in the area.

In 1986, we established 20-mile- (32-km-) long road transects in each of five counties that had relatively high densities of shrikes (Clay, Sherburne, Morrison, Lac Qui Parle, and Goodhue). Once a week from 4 July through 4 August in 1986 and 1987, we searched for shrikes along these census routes. Observers stopped every ½ mile (804 m) and scanned a ¼-mile- (402-m-) radius circle with binoculars for five minutes.

In 1986 and 1987, we monitored 61 nest sites at 3–5-day intervals until the young left the nest or the nest failed. Each nestling was distinctly marked with colored dye on the breast feathers 1–2 days prior to fledging. Data were collected on clutch size, hatching success (percent of eggs that hatch), fledging success (percent of young that fledge), and nest fate (number of nests that fledged ≥ 1 young). We calculated daily nest survival rates using the "Mayfield method" (Mayfield 1961). Nest success was calculated by raising the daily nest survival rate to the 35^{th} power (i.e., the average length of a nesting cycle). In cases where an entire near-fledging-age brood disappeared simultaneously and fledglings were not observed near the nest site on subsequent visits, we concluded that the nest had failed. Each nestling was banded with a U.S. Fish and Wildlife Service aluminum legband.

Each year we trapped adult shrikes during the breeding season using modified versions of a Bal-Chatri trap (Burger and Mueller 1959) or a Potter trap (Blake 1951). Lab mice and

Zebra Finches (*Taeniopygia guttata*) were used as lures in the traps. In 1986, 1987, and 1988, we trapped 9%, 29%, and 32% of the known adults, respectively. We concentrated trapping efforts in areas where we had banded birds in previous years. Trapping efforts were greater in 1987 and 1988 than in 1986. In 1988, 80% of our trap attempts were made in territories where birds were banded in 1987.

We constructed a stochastic model of the dynamics of a hypothetical Loggerhead Shrike population based on productivity per pair, annual adult survival rate, and annual juvenile survival rate. Productivity was a normally distributed stochastic function with a mean value taken from our data. We assumed that all adult birds breed, as we found no evidence of nonbreeders in our population, even though we had a good likelihood of finding them if they existed. Annual adult survival was a normally distributed stochastic function. We used territory reoccupancy rates from our study to estimate the annual adult survival rate, the assumptions being that males return to their previous breeding territory if they survive the winter, that male survival rate equals female survival rate, and that there is always an even sex ratio. There are no estimates of annual survival rates for juvenile Loggerhead Shrikes. Therefore, in our model, first-year survival rate was assumed to be a fraction of the adult survival rate for that year. We used the mean ratio of juvenile-to-adult survival calculated from Woolfenden and Fitzpatrick's (1984) data on Scrub Jays (*Aphelocoma coerulescens*), a similar-sized passerine, to estimate the mean value of this fraction. We multiplied that fraction, which is a normally distributed stochastic function, by our estimate of adult survival to estimate juvenile survival rate each year. Because there are no long-term studies (>5 years in duration) of year-to-year variations in shrike population parameters, we used results of Woolfenden and Fitzpatrick's (1984) long-term study of Scrub Jays to estimate the coefficients of variation of our model parameters.

Our model begins with a population of breeding shrikes and then predicts the population's size in subsequent years using the following equation:

$$N_t = N_{t-1}(S_a) + N_{t-1}(P/2)(S_j)$$

where N_t = size of the breeding population in year t, S_a = annual survival rate of adults, S_j = annual survival rate of juveniles, and P = number of young raised per breeding pair. During each annual cycle, a value for productivity and annual survival rate of adult birds is stochastically determined by randomly selecting a value from a normally distributed pool of values with a mean based on our field data and a coefficient of variation derived from the literature. A value for juvenile survival rate is stochastically determined by randomly selecting a value for the ratio of juvenile-to-adult survival, whose mean and coefficient of variation are taken from data on Scrub Jays, and multiplying it by the adult survival rate for that year. We ran our model 100 times and each time observed the change in population size over 50 years.

RESULTS

We collected nesting data on 48 breeding pairs of Loggerhead Shrikes in Minnesota during 1986 and 1987. The pairs were scattered throughout 11 counties and occurred at low densities. In 1986, 29 pairs of shrikes made 34 nest attempts, and in 1987, 19 pairs made 27 nest attempts. Most of the second nest attempts resulted after a failed first nest attempt. Five (10%) of the 48 pairs attempted to raise second broods; four of them were successful. In 1986, 24 breeding pairs were found along five 20-mile (32-km) survey routes. In 1987, 17 breeding pairs were found along these

TABLE 1
LOGGERHEAD SHRIKE NESTING DATA FROM MINNESOTA, 1986–1987

Parameter	Mean ± SD or percentage (N)		
	1986	1987	Both years
Clutch size	5.58 ± 1.38 (24)	5.73 ± 0.94 (22)	5.65 ± 1.17 (46)
Nestlings per nest	4.54 ± 2.20 (26)	3.80 ± 2.45 (25)	4.18 ± 2.33 (51)
Fledglings per nest	3.12 ± 2.17 (33)	2.89 ± 2.10 (27)	3.02 ± 2.17 (60)
Fledglings per pair	3.48 ± 1.91 (29)	4.11 ± 1.74 (19)	3.73 ± 1.82 (48)
% Hatching success	81 (24)	71 (22)	76 (46)
% Fledging success	66 (26)	77 (25)	72 (51)
% Nests that fledged >1 young	74 (34)	70 (27)	73 (61)
% Pairs that fledged >1 young	83 (29)	84 (19)	83 (48)
Mayfield estimate of nest success (%)	66 (24)	56 (23)	62 (47)

same survey routes; the surveyed population had experienced a 29% decline in one year.

Productivity data.—The mean clutch size was 5.65 ± 1.17 [SD], (N = 46), ranging from a minimum of three eggs to a maximum of seven eggs. The modal clutch size was six. On average, 4.18 ± 2.33 eggs hatched per nest (N = 51), 3.02 ± 2.07 young fledged per nesting attempt (N = 60), and 3.73 ± 1.82 young fledged per pair (N = 48). There were no significant differences between years in clutch size, number of eggs hatched, number of young fledged per nest, or number of young fledged per pair ($P > 0.10$ in all cases, students t-test). See Table 1 for a summary of nesting parameters.

Of 48 pairs of shrikes, 40 (83%) successfully fledged at least one young. However, because of renesting attempts, only 74% of all nest attempts successfully fledged at least one young. Hatching success was higher in 1986 (81%) than in 1987 (71%) ($\chi^2 = 3.006$, $0.10 > P > 0.05$). However, fledging success was lower in 1986 (66%) than in 1987 (77%) ($\chi^2 = 2.940$, $0.10 > P > 0.05$). On average, 55% of eggs laid resulted in fledged young. Using Mayfield's estimate of reproductive success based on exposure days, we calculated a reproductive success of 62% (Table 1).

Survival data.—We found 37 occupied territories in 1986, 22 in 1987, and 16 in 1988. In 1987, 15 (41%) of the 37 breeding territories used the previous year were reoccupied; in 1988, 13 (59%) of the 22 breeding territories used in 1987 were reoccupied. When both seasons' data were combined, the average reoccupancy rate was 47%.

TABLE 2
PARAMETERS IN A MODEL OF THE DYNAMICS OF A HYPOTHETICAL LOGGERHEAD SHRIKE POPULATION

Model parameter	Mean value	Coefficient of variation (%)[a]
Productivity per pair	3.73	29
Annual adult survival	0.47	11
Ratio of juvenile to adult survival	0.41[a]	22
Annual juvenile survival	0.19	36

[a] From Woolfenden and Fitzpatrick (1984).

We trapped and banded 25 adult Loggerhead Shrikes. Of the five territories in which we had banded adults in 1986, one was reoccupied in 1987. In 1988, eight of 10 territories occupied by banded adult birds in 1987 were reoccupied; we successfully trapped at least one adult at each of seven of these territories. Seven of the banded adults from 1987 were males, and three (43%) of these banded males returned to reoccupy their previous year's territories. We neither trapped nor observed in subsequent years any of the 196 shrikes we banded as nestlings in 1986 and 1987.

Population modeling.—Table 2 summarizes the model parameters and their corresponding coefficients of variation. Based on 100 simulations, the model predicted a 20% (range 14–30%) mean annual rate of decline for the hypothetical Loggerhead Shrike population. This rate of decline leads to a halving of the population's size every 3.5 years.

To determine which of the demographic parameters had the greatest influence on the rate of change in population size, we tested the sensitivity of the model to changes in each of its components. We sequentially multiplied each model parameter's mean by 105%, while holding the other two variables constant, and ran the model 100 times. The population's rate of change decreased by 15% (i.e., from 20% to 17%) in response to a 5% increase in each of the model's parameters. Thus, each of the parameters exerted the same amount of influence on the rate of change in population size.

DISCUSSION

Shrike demography.—Reported values of nesting success of shrikes range from 43% in Alabama (Siegel 1980) to 80% in Illinois (Graber et al. 1973). The lowest value, 43%, is well below the second lowest value of 62% (Luukkonen 1987), indicating that values greater than 60% are more typical of Loggerhead Shrike nesting success. Ricklefs (1973) notes that nest success of temperate zone passerines with open nests averages 47%, suggesting that Loggerhead Shrikes have relatively high reproductive success for a passerine.

The number of young produced per female in Minnesota (3.73) closely resembles values from other recent shrike studies (Erdman 1970, Porter et al. 1975, Gawlik 1988). Data from our study and others suggest that Loggerhead Shrikes are experiencing typical nesting success for an open-nesting passerine species in the temperate zone.

Because there have been no long-term studies of marked shrike populations, our estimates of survival rates must be inferred. Using territory reoccupancy rate to estimate annual adult survival assumes that those males that did not return to their previous year's territories are dead. Although we cannot strictly test this assumption, our reoccupancy rate (47%) did closely resemble our adult male band-return rate (43%), indicating that the assumption is valid. Kridelbaugh (1983) reported that 47% of banded male shrikes returned to their territories of the previous year and that 54% of the previous year's territories were reoccupied. Likewise, A. Blumton (pers. comm.) reported a 50% return rate of banded adult shrikes in Virginia. Ricklefs (1973) notes that adult survivorship is generally low among small land birds (40–60% in most temperate passerines). Our estimate of adult survival is, therefore, not at all unusual for a temperate zone passerine.

There are few data that reveal the relationship between adult and juvenile survival rates in passerines. We calculated juvenile survival to be, on average, 41% of the adult survival rate, based on data from Woolfenden and Fitzpatrick's (1984) study of Scrub Jays. Ricklefs (1973) states that, in general, juvenile survival rates of passerines are typically one-quarter to one-half of the adult survival rate. Our estimate of juvenile-to-adult survival ratio is typical of values for other passerines.

The annual survival rates of adult and juvenile Loggerhead Shrikes in the upper midwest, despite being within the range typical of passerines, are too low to maintain population stability. Henney et al. (1970, Table 1) provides a deterministic model which estimates the productivity per pair required to maintain a stable population, given survival rates for adult and juvenile age classes. If our population is surviving at average rates of 47% and 19% for adults and juveniles, respectively, approximately 5.5 young must be produced per pair. No shrike population is known to produce this many young, which would require almost 100% nest success or consistently successful double brooding.

Because our Minnesota shrike population is achieving good fledging success, and habitat conditions on the breeding range seem more than adequate to accommodate the present population (Brooks and Temple

1986), it seems likely that survival of birds while they are on the summer breeding range is also good. We found no evidence of adult mortality during the breeding season, and survival of post-fledging birds for two weeks post fledging seemed to be high, although we did not precisely estimate it. Overwinter survival on the nonbreeding range is, therefore, a likely point in the shrike's annual cycle to look for evidence of problems. In a six-year study of a declining population of Red-backed Shrikes (*Lanius collurio*) in Britain, Ash (1970) suggested that reductions in annual survival rates were responsible for that population's decline, rather than a reduction in the production of young.

Possible causes of low overwinter survival.—Although the exact location of our Minnesota population's wintering quarters is yet unknown, Burnside (1987) found that banded shrikes from northern mid-continental populations have been recovered during the winter in Texas, Arkansas, Oklahoma, Mississippi, Louisiana, Kansas, and Missouri. Root (1988) showed, in an analysis of Christmas Bird Count data, that the highest concentrations of wintering Loggerhead Shrikes are found in the gulf coast states, primarily Texas, Louisiana, Mississippi, and Alabama.

Burnside and Shepherd (1985) suggested that recent land-use changes have eliminated prime shrike habitat in Arkansas. Kridelbaugh (1981) attributed the decline of the Loggerhead Shrike in Missouri to the conversion of pastureland and hayfields to row crops. The extensive conversion of pastureland and old fields to cereal-crop production has resulted in the elimination of large areas of grassland habitat throughout the gulf coast and adjacent regions (Neff and Meanley 1957; USDA 1950, 1975, 1986).

There is good evidence indicating that these habitat changes have impacted populations of birds that winter in the region. The best documented population responses have been dramatic increases in species that feed on grain, notably members of the family Icteridae (Stepney 1975). Because these wintering blackbirds feed primarily on cultivated grains, their populations have steadily increased over the same 50-year period that shrike populations sharing the same wintering areas have steadily decreased (Temple and Temple 1976, Brittingham and Temple 1983).

The impact of this loss of wintering habitat for migrating shrikes from northern breeding areas is made even more threatening by the presence of resident shrike populations throughout these southern states (Miller 1931). Southern populations of shrikes are nonmigratory and defend winter territories (Gawlik 1988, A. Blumton, pers. comm.). Habitat alterations in the gulf coast region and adjacent states have apparently reduced the habitat available for resident shrikes; their populations have declined (Robbins et al. 1986, Burnside 1987), although not as severely as more northerly populations. If resident shrike populations are being limited by habitat availability, migrant shrikes wintering in the same area are almost certainly being forced to occupy marginal habitats that are not being held by territorial residents, and this reduces overwinter survival to inadequately low levels.

Population declines.—The possibility that a local or regional shrike population could decline and become extirpated within a few decades is an alarming prospect, but Anderson and Duzan (1978) provide evidence of one such extirpation of a local population of Loggerhead Shrikes in central Illinois. The results of the Breeding Bird Survey indicate that the entire upper midwestern shrike population (including the states of Minnesota, Iowa, Illinois, Wisconsin, Michigan, and Indiana) has been declining at a rate of 6% per year from 1966–1987 (Robbins et al. 1986, S. Droege, pers. comm.). Our data suggest even more severe declines in local populations in Minnesota.

Our population model, although requiring the use of several key assumptions about shrike demography, strongly suggests that the causes of declines in midwestern shrike populations are probably associated with overwinter survival. Research attention should now focus on learning more about midwestern shrikes on their wintering areas and how habitat management there could reduce the population's rate of decline. It seems unlikely that conservation efforts on midwestern breeding areas will succeed in slowing or reversing the declines in these shrike populations if they are being limited by factors on their nonbreeding range.

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